Project Report: Evolution of Atmospheric O_2, Climate, and Biosphere − Brian W. Stewart

Lead Team:	***Pennsylvania State University***
Project Title:	***Evolution of Atmospheric O_2, Climate, and Biosphere − Brian W. Stewart***
Project Investigator:	***Brian Stewart***

Project Progress

Effects of climate on mineral weathering rates. We continue work with Associate Member O.A. Chadwick in applying radiogenic isotopes to understand regional and global patterns of soil weathering and nutrient cycling. Weathering models developed from an isotopic investigation of a basaltic soil climosequence in Hawaii indicate that a major acceleration in mineral weathering rates occurs above mean annual precipitation values of 120−160 cm/yr, suggesting a non−linear "threshold" for weathering on a volcanic substrate.

Sources of solutes to the oceans. Marine carbonates provide a global record of solutes introduced into the oceans by terrestrial weathering and hydrothermal exchange. In a study of major streams of the ~8500 km^2 Owens Lake, California drainage basin, we showed that hydrothermal exchange and acid production by sulfide reduction may be the most important factors in the basin−averaged $^{87}Sr/^{86}Sr$, even during a major climate shift. Neodymium isotope variations in clastic and authigenic sediments in Owens Lake sediments indicate a systematic shift in the nature of the clastic sediment source related to a global climate shift from glacial to interglacial conditions. These studies help to clarify the relative importance of climate and solute sources to the ocean, and provide guidance for understanding the geochemical record preserved in ancient marine carbonates.

Stratification in Precambrian Oceans. Our neodymium isotope results from the Hamersley Basin (2.5−2.6 Ga) of Western Australia (in collaboration with M. Bau, Pennsylvania State Astrobiology Research Center (PSARC)) indicate that the shallow marine carbonates have an isotopic signature that is surprisingly close to the deeper banded iron formation deposits; these results argue against a Precambrian ocean that was stratified with respect to REE and Fe. Neodymium isotope data from the deeper marine carbonates define an isochron with an age of ~2.1 Ga, which is consistent with a previously inferred metamorphic event.

Planetary Geochronology. Extending our understanding of the Earth's evolution to the terrestrial planets requires strong geochronologic constraints for planetary surface features. As an outgrowth of our efforts to determine ages of rock units at the Earth's surface, we are continuing to make progress in our work with G. Cardell (Jet Propulsion Laboratory (JPL)) and Associate Member D.A. Crown (Planetary Science Institute) to develop an instrument capable of *in situ* geochronology of surface igneous rocks on Mars.

Highlights

- Modeling of weathering in a basaltic soil climosequence demonstrates a nonlinear response of weathering rate to mean annual precipitation. Weathering rates show a significant acceleration above 120−160 cm rainfall/year.

- An investigation of solute sources in the Owens Lake, California, drainage basin indicates that continental inputs of strontium to the ancient oceans could be strongly biased by hydrothermal systems and sulfide oxidation.

- A neodymium isotope study of carbonates from the ~2.6 Ga Hamersley Formation of Western Australia suggests that the ancient oceans were not strongly stratified with respect to rare earth elements (and iron), even before the purported rise in atmospheric oxygen.

- Samarium−neodymium data from Hamersley Formation carbonate define an isochron of ~2.1 Ga, significantly younger than the age of deposition (~2.6 Ga). This suggests that rare earth elements are mobile enough in carbonate to isotopically homogenize over a scale of tens of meters during metamorphism.

Roadmap Objectives

- ***Objective No. 5:*** Linking Planetary Biological Evolution
- ***Objective No. 8:*** Past Present Life on Mars
- ***Objective No. 12:*** Effects of Climate Geology on Habitability
- ***Objective No. 14:*** Ecosystem Response to Rapid Environmental Change

Mission Involvement

Mission Class*	***Mission Name (for class 1 or 2) OR Concept (for class 3)***	***Type of Involvement*****
3	Mars in situ exploration	Co−I, Science Team Member

* Mission Class: Select 1 of 3 Mission Class types below to classify your project:
1. Now flying OR Funded & in development (e.g., Mars Odyssey, MER 2003, Kepler)
2. Named mission under study / in development, but not yet funded (e.g., TPF,

Mars Lander 2009)
3. Long−lead future mission / societal issues (e.g., far−future Mars or Europa, biomarkers, life definition)

** Type of Involvement = Role / Relationship with Mission
Specify one (or more) of the following: PI, Co−I, Science Team member, planning support, data analysis, background research, instrument/payload development, research or analysis techniques, other (specify).

B.W. Stewart and G. Cardell are PIs and R.C. Capo and D.A. Crown are Co−Is on a funded NASA Planetary Instrument Definition and Development Program (PIDDP) project at JPL to develop an in situ geochronology instrument for planetary surface deployment. Such an instrument would be a high priority for future Mars lander missions, as Mars surface geochronology is a key component of NASA's planetary exploration road map.

Cross Team Collaborations

We have started a collaboration with A.D. Anbar of the Harvard and JPL teams. We are working to develop better methods for measuring iron isotope ratios in ancient sediments. We initiated a joint effort in preparing a mixed tracer solution for Fe isotope analysis, with the goals of achieving higher measurement precision and facilitating interlaboratory comparison of Fe isotope results.